CONTENTS

1. PREAMBLE ............................................................................................................. 3
2. DEVELOPMENT OF THE CONCEPT MODEL ...................................................... 3
   2.1 KEY REFERENCE BEHAVIOURS ...................................................................... 3
   2.2 THE CONCEPT MODEL AND THE ENERGY CULTURES FRAMEWORK .......... 8
3. SIMULATION MODEL OVERVIEW ......................................................................... 11
4. MODEL SECTORS .................................................................................................... 13
   4.1 POPULATION .................................................................................................... 14
   4.2 TRIPS .................................................................................................................. 15
   4.3 CONGESTION & ROAD CAPACITY ................................................................. 16
   4.4 TRAVEL TIME ................................................................................................... 18
   4.5 TRAVEL MODE COSTS .................................................................................... 19
   4.6 PUBLIC TRANSPORT INFRASTRUCTURE ....................................................... 21
   4.7 MODE SHIFTING ............................................................................................... 23
   4.8 CO₂ EMISSIONS ................................................................................................. 24
5. DEVELOPMENT OF TTNZ MODEL: VERSION 2.0 ............................................... 25
1. **PREAMBLE**

This is a reference guide for the “Modelling Transport Transitions” System Dynamics (SD) model, providing a detailed presentation of the model. Version 1.0 is not a fully validated model and its outputs at this stage are not to be viewed as representing plausible transport transition dynamics. Instead, the model provides an initial description of the structure of the transport transitions model and a framework to guide future development.

As it's current stage of development, the model, and this accompanying report, provide specific indications of the data required to be collected and/or validated for it to become a tool to explore transport transitions in New Zealand. The report also outlines the steps needed for this to occur.

2. **DEVELOPMENT OF THE CONCEPT MODEL**

This section describes the concept model that emerged from a workshop with members of the Energy Cultures project team held on 3 June 2014 and subsequent interviews with individuals to clarify points raised in that workshop.

The purpose of this work was to develop a clear understanding of the scope of the simulation model and the key questions to address.

2.1 **Key Reference Behaviours**

One of the key tasks undertaken in the workshop was to establish the key variables that the model should focus on. The questions discussed was:

“What are the key variables we need to consider in exploring transport transitions?”

Group members were asked to think of at least three key variables and then to describe them in the form of a ‘Reference Behaviour Pattern’ (RBP). That is, a time series graph that portrays the historical pattern of the variable, its likely future trajectory if current trends continue, and a preferred future trajectory, indicating a successful transition to a sustainable transport future.

20 RBPs were produce and then brought together into nine clusters. These were:

- The cost of fossil fuels at the pump
- The cost of fossil fuels for business
- Mode choice
- Type of fuel used
- Use of public transport
- Impact on CO₂
- Alternatives to transport
- Contextual factors that may drive or inhibit change
- Demographics, including generational change

The following sections describe each of these clusters, with an illustrative RBP. Beyond providing some insight into the variable itself, the RBPs were used to guide initial parameters used in the model and ongoing data collection.
Cost of Fossil Fuels at the Pump

As a major element of transport costs, the cost of fossil fuels have risen over the last few decades and are expected to continue rising. Interesting to note that ‘success’ for this variable is an even higher rise that expected, as that will help shift people to more fuel efficient vehicles or to other more sustainable transport modes. A typical RBP highlighting this is shown below:

This is indicative of the view that the relatively low price of fossil fuels has been a major factor in their continued use, and significant price rises are seen as one factor that may support a change to more sustainable fuels.

Cost of Fossil Fuels to Business

For this variable the concern was different. The view here is that the cost of fossil fuels has been rising for business and ‘success’ would be a fall in that price. From a transition perspective this could occur if the use of fossil fuels declined, being replaced by either i) more efficient use of those fuels and/or ii) greater use of renewable energy sources. This pattern is shown below:
**Mode Choice**

This variable is concerned with the utilisation of different travel modes. The following RBP focus on the utilisation of public transport with success being associated with an increase over time. An interesting aspect of this pattern however is that utilisation has remained largely unchanged, although it is expected to rise in the future.

![Graph of Mode Choice](image)

**Type of Fuel Use**

As the following graph shows the percentage of transport using non-fossil fuels has stayed relatively unchanged for most of the 20th Century. Success will see a significant rise in the use of renewable fuel sources. D = desired, E = expected, F = feared.

![Graph of Fuel Use](image)

**Use of Public Transport**

The use of public transport is considered to have been low for decades and success will entail a significant increase.
**Impact on CO2**

This variable directly addresses issues of climate change and the impact of transport fuels upon levels of CO2 in the atmosphere. Success in this context will deliver substantial reduction in carbon emissions from transport.

**Alternatives To Transport**

This variable taps into recent trends in the use of social media that is having an impact on the importance of physical travel, with relationships and work being able to be maintained ‘on-line’.

**Contextual factors that may drive or inhibit change**

The focus here is on contextual factors that are likely to affect the transition. These include the marketplace and/or technology to support the move away from fossil fuels:
Another is the attitude that business has towards change:

Demographics, Including Generational Change

A major focus here was on ‘generation Y’ and their changing attitudes towards cars, evidenced by much lower levels of car licenses and car ownership than previous generations.
2.2 The Concept Model and the Energy Cultures Framework

Following the development of these RBP the group explored that factors that would affect them. Discussions led to the emergence of 42 concepts that could have an impact upon the behaviours shown above. These were:

- relative costs of fossil fuels
- technological advancements
- current infrastructure constraints
- vested interests in fossil fuels
- really cheap PV
- current concerns about health impact of current lifestyles
- changing attitudes of youth towards licensing etc.
- emergence of new business models
- impact of advertising
- usage of public transport
- efficiency becomes the norm
- lobbying to keep business as usual
- concern for security of supply
- understanding the life cycle costs
- political instability overseas
- development of cost effective alternative fuels in NZ
- ageing population
- global shift in type of vehicle manufactured
- cost of insurance
- number of EVs
- increasing concern about climate change
- short-term goals of the government
- battery storage for vehicles
- infrastructure available for alternatives
- vested interests in power companies to sell more electricity
- lifestyle aspirations towards sustainable transport
- impact of inequality
- driverless cars
- marketplace that supports transition shifts
- perception towards public transport
- increasing interest in efficiency
- measuring and feedback of CO2 emissions
- perception to different transport modes
- interest in the cleanliness of the source of fuel
- price on carbon
- development of cost effective biofuels in NZ
- impact of Gen Y as a cohort
- urban density
- financial impact of adverse events
- more efficient ICEs
- concern about environmental impact

These were then clustered and overlaid onto the Energy Cultures Framework, to provide a concept model to guide the development of the full simulation model. This is shown below:
Each of these are discussed below with some implications for the development of the simulation model

**Personal Preferences:** The model sector on personal preferences will focus on concerns about, climate change, health effects of pollution and environmental concerns.

**Mode Choice:** Mode choice focuses on the short-term choice of transport modality, for example, whether a person takes a car to work or catches a bus. The mode choice sector will need to model the trips taken, and the average length of trips taken, across a number of modalities, especially private vehicles, public transport and active transport.

**Vehicle Choice:** Vehicle choice concerns the longer-term choices of whether a person decides to buy a car or not and, if so, what sort of car they buy. These options will need to include a standard internal combustion engine (ICE), a fuel efficient ICE, which will include hybrids, or an electric vehicle (EV).

**Transport Infrastructure:** This will focus on investment in transport infrastructure, as this will have a significant impact upon the attractiveness of each of the options, thus affecting uptake. The model will need to include the investment in new infrastructure and the maintenance of existing infrastructure.

**Demographics:** This will model the population within the age groups, 15 to 39, 40 to 64, and 65 plus. These particular age groups have been chosen they conform to standard age groupings used in census data. Having three age groups will also enable the model to track the 'gen Y' population (15 to 39) as well as the increase in the number of older people (65 plus).
**Economics of Fossil Fuels**: This will need to look at international fuel prices as well as local prices. This will enable the model to explore changes in exchange rates, fuel taxes and international and local carbon taxes.

**Technology**: This will look at technologies that are, or as seen to be, important in affecting the attractiveness of future travel modalities, for example, improvements in battery technologies affecting price and performance of electric vehicles, and integrated ticketing technologies affecting the quality of public transport.

This initial work provided the information to guide both the focus and scope of the simulation model. The following sections describe the simulation model in more detail as well as the data that was used and the data that is required.
3. **Simulation Model Overview**

The Transport Transitions Model (TTNZ) is a Systems Dynamics (SD) model, which is being developed to assist the Energy Cultures project team capture key threads of their research, alongside other research and empirical data, in a simulation model, which could be used to explore interventions aimed at shifting New Zealand’s transport system onto a more sustainable footing.

SD methodology was developed in the 1950’s (Forrester, 1958) and has been used to model many areas of transport – including transport transitions to greater use of public and active transport, as well as new fuel types – especially those involving complex causal pathways with intermediate variables, delays, nonlinearities, and feedback loops. Some of these SD models have focused on policies to achieve sustainable mobility (Armenia et al., 2010), Ruutu et al., (2013)), while others have focused more specifically on the transition challenges (Struben and Sterman, 2008), urban transport systems (Gomez-Quintero and Guzman-Abello, 2012), or specific mode types such as electric vehicles (Stephan and Feller, 2009) and active transport modes (Macmillan et al., 2014). Each of these has influenced the development of TTNZ model.

Furthermore the model has been developed as part of the Energy Cultures research project (Stephenson et al., 2010). Work began on the model in 2014, based on workshops and meetings with members of the Energy Cultures project team. Additional input was obtained from industry and government representatives on the Energy Cultures reference panel.

An overview of the model’s causal structure, which was developed on the basis of the concept model discussed above is shown in figure 1. While this is a highly simplified view of the model its purpose is to show the key casual connections and the feedback loops within which they are embedded. The key proximal drivers of shift between modes are the relative costs of each mode and their relative travel times. Travel costs for cars are driven by a mix of purchase and operational costs while public transport costs for the traveller are driven by fares. Relative travel times are influenced by congestion, levels of vehicle ownership and investment in public transport infrastructure.

**NOTE:** The current version of the model is localised to Auckland.
4. **MODEL SECTORS**

The following diagram shows the sectors in the TTNZ simulation model. The following sections describe each sector in detail.

*Figure 2: Simulation Model Sector Map*

This is a high level sector map showing the key sectors in the model and their connections. In line with the model overview diagram, figure 1, this sector map shows that shifts in mode are driven by a combination of travel time and costs.
4.1 Population

The following diagram shows the model structure used to simulate population.

![Population Sector Diagram](image)

**Figure 3: Population Sector**

The population structure in the model is relatively simple and only breaks the population into three age bands, young adult, 15 to 39; adult 40 to 64; and older adult 65 plus. The model does not disaggregate by either gender, ethnicity, or socio-economic status.

**Table 1: Population Sector Variable Definitions and Data Sources**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
</table>
| Population initial        | This is the population of Auckland, as at June 2014, that was used to initialise the model:  
15 to 39: 557,100  
40 to 64: 478,900  
| Population growth rate    | This is the population growth rate per year for each of the population age groups,  
15. to 39: 1.3%  
40 to 64: 1.25%  
65 plus: 3.74%      | New Zealand Statistics Department: Area unit population projections, by age and sex, 2013(base)-2043 |
| Urban rural ratio         | This is the ratio of people living in rural and urban districts within Auckland  
Percent people living in urban areas: 0.75 | Ministry of Transport (2014): Future Demand: Model overview and user guide. |
4.2 Trips

The following diagram shows the model structure used to simulate trips.

Figure 4: Trips Sector

In this sector, trips over time are based on the initial vehicle trips per person per year, in the base year, which is then adjusted for the three age groups. These trips change over time based on population growth and the percentage of total trips that are taken by public transport. So, the growth in vehicle trips shown in the graph, ‘total trips by car’ is driven by population growth and the declining percentage of people taking trips by public transport, seen in the small rectangle at the top left. That is driven by another part of the model, discussed below.

In addition the variable ‘gen y effect’ has been included but at this stage has no impact. It is included so that the impact of changing driving patterns amongst gen y, currently being researched by the project team, can be included in the model once the research outputs are available.

Table 2: Trip Sector Variable Definitions and Data Sources

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle trips per person per year</td>
<td>The number of trip legs per person, taken per year. The categories used to initialise the model were: Car/van driver: 649 Public Transport: 49</td>
<td>New Zealand Household Travel Survey 2003 – 2014. Travel by residents of Auckland Area (all ages), Ministry of Transport</td>
</tr>
<tr>
<td>Gen y effect</td>
<td>This variable has been included to capture the impact of changing travel practices by ‘gen y’. There is no data currently available from the research to input into the model, so it currently has no effect on model outputs.</td>
<td>EC2 research project</td>
</tr>
</tbody>
</table>
4.3 Congestion & Road Capacity

The following diagram shows the model structure used to simulate congestion and road capacity.

Figure 5: Congestion and Road Capacity Sector

This sector of the model simulates the link between congestion and investment in new road capacity. The key aspects of the model structure are the links between road capacity and congestion and how much congestion policy makes are willing to tolerate, ‘reference congestion policy’. To show how this affects model behaviour two scenario are shown above. Run 1 has the ‘reference congestion policy set at 0.8, whilst Run 2 was set at 0.92. The higher number simply reflects a greater tolerance for congestion and results in less investment in road capacity, allowing congestion to rise to the ‘acceptable’ level. As can be seen, congestion is higher in Run 2 than in Run 1. For the model to reflect ‘real’ conditions work needs to be undertaken to obtain data on ‘road capacity and ‘congestion’ and obtain a more precise understanding of how changes in road capacity affect congestion.

Table 3: Congestion and Road Capacity Sector Variable Definitions and Data Sources

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road capacity</td>
<td>Road capacity is measured by vehicles per hour or per day. The problem the model faces at this point is to define the scope i.e. what roads are included in determining capacity. Currently the model is localised to Auckland, but further input is required to refine the scope to get appropriate figures for road capacity.</td>
<td>Need to review with EC2 team and discuss with subject matter experts.</td>
</tr>
<tr>
<td>Congestion</td>
<td>There is debate about to measure travel congestion so expert input is needed. Some measures relate to travel time, others to traffic volumes and/or density.</td>
<td>As above, input is needed from subject matter experts.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
<td>As above</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Time to build roads</td>
<td>This is an important variable as it creates the delay between the decision to add capacity and the time that it actually arrives. As this is highly dependant on the nature and size of the roading project further expert input is needed to obtain realistic parameters for this variable.</td>
<td></td>
</tr>
<tr>
<td>Reference congestion policy</td>
<td>As this is a proxy for ‘target levels’ of congestion and affects the point at which congestion triggers investment in new road capacity it does not need empirical data. It is an input variable that can be used to explore different scenarios that reflect a range of attitudes and policy options in regards to congestion and the common response of increasing road capacity</td>
<td></td>
</tr>
</tbody>
</table>
4.4 Travel Time

The following diagram shows the model structure used to simulate travel time.

Figure 6: Travel Time Sector

The key drivers of travel time in the model are congestion and investment in public transport infrastructure. These are shown in the top right-hand side of the model. The run shown above shows travel time for cars increasing. This is due to the increase in congestion and the drop in the percentage of people travelling by public transport. This stimulates investment in road capacity which then levels off travel time. As discussed above, in section 4.3, this level is determined by the variable, ‘reference congestion policy’.

Table 4: Travel Time Sector Variable Definitions and Data Sources

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average trip time initial</td>
<td>This establishes the initial trip times for cars and buses. The average travel times to regional growth centres, which are the initial ties used in the model are: Car: 18 minutes, Public transport: 49.6 minutes. Average PT journey times are therefore 2.7 times longer than a car.</td>
<td>Auckland Road Pricing Study Auckland Regional Transport Authority, Section 6.7 pp 35-41. June 2008.</td>
</tr>
<tr>
<td>Trip fraction initial</td>
<td>This allocates total trips across the different modalities. Car/Motorcycle: 78%, Public Transport: 4%, Active Transport: 18%.</td>
<td>New Zealand Household Travel Survey 2003 – 2014. Travel by residents of Auckland Area (all ages), Ministry of Transport.</td>
</tr>
</tbody>
</table>
4.5 Travel Mode Costs

The following diagram shows the model structure used to simulate travel mode costs

**Figure 7: Travel Mode Costs Sector**

This sector provides the structure for calculating travel mode costs. Vehicle costs are split into ‘normal ICE’, ‘economic ICE’ and ‘EV’. These are shown in red on the left-hand side and bottom of the model above and include, fuel consumption EV, EV subsidies and rebates, fixed costs per km, riders per car, international fuel price, fuel taxes, fuel consumption normal ICE, and fuel consumption economic ICE. This input data, along with vehicle usage, determined by ‘vehicle trip legs per person per year’ [trips sector] determines yearly travel costs. Note, this structure calculates operating costs only. Purchase costs are not included, although they need to be included at some stage as they will have a significant impact upon decisions to purchase. Public transport costs are based on fare structures.

The costs of each modality are then compared against each other to calculate the costs advantage of each mode. Three examples of costs advantage is shown in the graph. [NOTE: these are not valid numbers as the input variables have not been validated]. Cost advantage calculates how much you could save by shifting modes. So, in the default run EV has a cost advantage over a normal car of 0.29. That means a person could reduce their annual travel costs by 29% by shifting from a normal car to an EV. The cost advantage of an economic car over over a normal car is 0.14, that is a shift to an economic car could reduce running costs by 14%. 
As noted above these are not ‘real’ values as the input data is not valid. However, the model structure is able to create these costs advantage figures as soon as the input data can be obtained.

Table 5: Travel Mode Costs Sector Variable Definitions and Data Sources

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel consumption EV</td>
<td>This is initially set at ‘0’ however as public charging facilities grow there will be cost associated with charging which is the EV equivalent of fuel consumption</td>
<td>Input is needed from the Energy Cultures project team and subject matter experts</td>
</tr>
<tr>
<td>Fuel consumption ‘normal’ car</td>
<td>Fuel consumption of a normal car. Issues involved in getting appropriate data include defining what is meant by a normal car and obtaining the appropriate fuel consumption data</td>
<td>As above</td>
</tr>
<tr>
<td>Fuel consumption ‘economic’ car</td>
<td>Fuel consumption of an economic car.</td>
<td>As above</td>
</tr>
<tr>
<td>EV subsidies and rebates</td>
<td>Other than exemption from road user charges these do not exist. The variable is included as it would allow the development of policy scenarios such as the ‘feebates’ policy discussed in Barry Barton’s paper.</td>
<td>NB: link to report by Barry Barton (feebates)</td>
</tr>
<tr>
<td>Fixed costs per kilometre</td>
<td>This equates to how much a vehicle owner would have to spend each year to run their vehicles. This requires input from relevant subject matter experts.</td>
<td>As above</td>
</tr>
<tr>
<td>Riders per car</td>
<td>This allows for cost contributions to be made by car sharing, which is one of the policy options often discussed in terms of vehicle use.</td>
<td>As above</td>
</tr>
<tr>
<td>International fuel price</td>
<td>This is a key component in determining ‘price at the pump’ and allows the model to be affected by the international context.</td>
<td>As above</td>
</tr>
<tr>
<td>Fuel taxes</td>
<td>This refers to local taxes and allows national and regional policies to be included in the model.</td>
<td>As above</td>
</tr>
<tr>
<td>Public transport fares</td>
<td>This refers to the average fare paid by users of public transport. This will need data on average trip length and costs</td>
<td>As above</td>
</tr>
</tbody>
</table>
### 4.6 Public Transport Infrastructure

The following diagram shows the model structure used to simulate public transport infrastructure.

![Public Transport Infrastructure Sector Diagram](image)

This sector focuses on the state of public transport infrastructure and its impact upon travel time. At this stage the model has a simple high-level structure that enables scenarios to be run that reflect different policy stances towards investment in public transport. However, to validate this sector more information is needed on indicators of public transport infrastructure that could be used to model the ‘quality’ of what currently exists and to add some specificity to what level of investment would deliver what level of gains. A second area that needs further input is the impact that public transport infrastructure would have on travel times. Current developments in Auckland’s public transport system may have information that could be used to inform this part of the model.

Because we have no validated data, public infrastructure is set at a nominal value of ‘1’ so that in the current version it has no impact upon the rest of the model.

**Table 6: Public Transport Infrastructure Sector Variable Definitions and Data Sources**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public transport infrastructure</td>
<td>As noted above input is needed not just to obtain valid data but to also provide input into what needs to be considered in this variable.</td>
<td></td>
</tr>
<tr>
<td>Public transport infrastructure asset lifetime</td>
<td>This determines how long the infrastructure lasts and therefore, what levels of maintenance is need to maintain it. This is highly aggregated in the current model, but would need to be specified in more detail for it to become valid.</td>
<td></td>
</tr>
<tr>
<td>Public transport infrastructure time</td>
<td>This affects how long it takes the infrastructure to come on stream and therefore incorporates delays into the mode for public transport development</td>
<td></td>
</tr>
</tbody>
</table>
4.7 Mode Shifting

The following diagram shows the model structure used to simulate mode shifting.

**Figure 9: Mode Shifting Sector**

This sector of the model is not currently runnable. The primary reason for this is that is is not yet clear how the key variables in the model, especially travel time and travel costs impact the pattern of shifting between travel modes. The work required here is more about developing a clear theory that can incorporate the variables in the model. The model structure is set to run but to finish this sector will require further input from the Energy Cultures project team as the next step. That would be enough to get this sector running. It could then be reviewed and modified by relevant subject matter experts.

The key structure of this sector allows shifting between the four modes currently operational in the model, ‘normal’ vehicles, ‘economic’ vehicles, EVs and public transport.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition rates</td>
<td>The model structure is based around people shifting from one mode to another and is currently set up to respond to changes in travel time and costs associated with each mode. The choice modelling and the household survey could provide input into people’s preferences and how they would respond the changes in cost and travel time.</td>
<td>EC2 Choice modelling, EC2 Household survey</td>
</tr>
</tbody>
</table>
4.8 CO\textsuperscript{2} Emissions

The following diagram shows the model structure used to simulate CO\textsuperscript{2} Emissions

**Figure 10: CO\textsuperscript{2} Sector**

This sector provides the opportunity to explore the impact on CO\textsuperscript{2} emissions of changing travel modes. The structure shown above calculates the CO\textsuperscript{2} emissions from cars, separating out ‘normal’ from ‘economic’ cars. The model is also set up to be able to incorporate shifts across to EVs and public transport, although the extract shown above only calculates the change as it relates to cars. As with all the graphs the numbers themselves do not reflect reality, but only show the capability of the model to explore these variables, each of which needs further input.

**Table 7: CO\textsuperscript{2} Emissions Sector Variable Definitions and Data Sources**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Data Sources</th>
</tr>
</thead>
</table>
| CO\textsuperscript{2} per litre of fuel | This measures the CO\textsuperscript{2} used per litre of fuel. Information used to specify this figure was obtained from a carbon calculation website. The method for calculating emissions is shown below. It should be noted that the current model use the data for petrol. The current version of the model does not differentiate between petrol and diesel engines, although it would be relatively simple to do. The calculation method is:  

**Diesel:**  
1 liter of diesel weighs 835 grammes. Diesel consist for 86.2\% of carbon, or 720 grammes of carbon per liter diesel. In order to combust this carbon to CO\textsubscript{2}, 1920 grammes of oxygen is needed. The sum is then 720 + 1920 = 2640 grammes of CO\textsubscript{2}/liter diesel. | http://www.ecoscore.be/en/how-calculate-co2-emission-level-fuel-consumption  
Accessed October 2015 |
An average consumption of 5 liters/100 km then corresponds to 5 l x 2640 g/l / 100 (per km) = 132 g CO2/km.

Petrol:
1 liter of petrol weighs 750 grammes. Petrol consists for 87% of carbon, or 652 grammes of carbon per liter of petrol. In order to combust this carbon to CO2, 1740 grammes of oxygen is needed. The sum is then 652 + 1740 = 2392 grammes of CO2/liter of petrol.

An average consumption of 5 liters/100 km then corresponds to 5 l x 2392 g/l / 100 (per km) = 120 g CO2/km.

Percentage of diesel and petrol engines in the fleet

As a first next step it would be useful to split out diesel from petrol engines. If further refinement was required splits could be made, based in information about the vehicle fleet into more specific subsets. Each however would need to be categorised as a ‘normal’ car or an ‘economic’ car to be consistent with other sectors in the model.

5. DEVELOPMENT OF TTNZ MODEL: VERSION 2.0

The current model is an attempt to create a simulatable framework, that integrates various strands of thinking within the Energy Cultures project, along with specific research outputs and international literature. While the structure is now capable of producing a model that ‘behaves in sensible ways’ the data that is informing that behaviour is currently not valid enough to produce outputs which can inform research and/or policy. So, while the model has made progress in simplifying the complex reality of transport transitions in a way that helps cut through that complexity and focus on key issues that will affect that transition, it has not reached the stage where its outputs are useful. To get to that point members of the EC2 project team and subject matter experts need to be involved in interrogating the structure that exists and in providing the data necessary to get the model to the next stage.

This input could happen in a number of ways however, if it is to develop momentum there needs to be a person within the EC2 team for whom getting the model to the next stage is an important part of their role. In terms of obtaining further input the EC2 Reference Panel could be used to tap into people who would have some time and expertise to work as part of a virtual team to refine the model structure and to improve the quality of data. Given the difficulties associated with bringing people together I would advocate a modified Delphi approach for this work. Such an approach has been used in a number of SD modelling projects overseas (Vennix and Gubbels, 1992) and in New Zealand (Rees, 1999). The basic flowchart of this process is shown below:
The work to date has focused on phases 1 and 2 and we now have a preliminary model. To involve the EC2 project team and subject matter experts in helping to develop the next version the first step would be a workshop to help people understand both the modelling method and the model as it currently exists. This would be a precursor to 2 or 3 Delphi rounds which would be used to finalise the model. These would be split into a group focusing on the model structure and data, and the other exploring the policy options that the model should be designed to explore. The outputs of each round (both 4a and 4b) would be used to inform the next iteration.

In 4a each participant would be given some background pertaining to the model and to issues surrounding transport transitions. The questionnaire would focus on specific relationships between variables in the model, which would be targeted at their areas of expertise.

4b would focus on identifying policy options that could potentially support transport transitions and to establish the criteria that could be used in selecting which policy options would be explored in the model. Feedback would also be used to help formulate how these options would be implemented in the model.

These Delphi process would help finalise the model which would then go through the normal process of testing as well as incorporating the input mechanisms needed to test the policy options agreed upon. Once completed a ‘policy workshop’ could be held to explore transport transition policies with the aid of what would now be a validated simulation model.
REFERENCES


